Cross-linguistic Effects in Spoken Word Recognition of Spanish and English Cognates

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Abstract

The present study investigates cross-linguistic cognate effects in spoken word recognition in native and nonnative speakers of Spanish and English. Specifically, the study examines the correlation between objective and subjective measures of cross-linguistic phonological similarity, whether cognate facilitation effects are observed in L1 and L2 auditory recognition, and how phonological overlap modulates auditory recognition of cognates. 120 participants will complete a similarity rating task in which they will listen to cognates and noncognates and rate their phonological similarity using a Likert scale. Additionally, participants will complete two auditory lexical decision tasks (in Spanish and English) in which they will encounter cognates, noncognates, and pseudowords. The findings will help determine the suitability of objective and subjective measures of phonological overlap and will provide evidence of the factors that modulate auditory lexical recognition.

Keywords: cognates, spoken word recognition, auditory processing, phonological overlap, orthographic overlap, lexical frequency.

Word count: 8209

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Introduction

Cognates are lexical items across languages that share meaning and high degrees of orthographic and phonological overlap. Cognates facilitate lexical processing compared to non-cognate words due to the increased cross-linguistic co-activation of cognate pairs (e.g., Dijkstra, Grainger, & van Heuven, 1999; Midgley, Holcomb, & Grainger, 2011; Peeters, Dijkstra, & Grainger, 2013). Defining cognates in phonological terms is always a difficult task. Cognates are rarely phonologically identical due to phonological and phonetic differences across languages, and in many cases, cognates may differ in most sounds but still cause facilitation effects (Sherkina, 2003). Some cognates have complete orthographic overlap but are not phonologically identical, which shows that phonological and orthographic overlap may not have a direct positive linear relationship. Despite the abundant research on cognates, there is no consensus about the definition and classification of cognates. Many studies do not provide a detailed description of what they regard as 'similar'. Available studies even measure cross-linguistic orthographic/phonological overlap using different criteria, which makes an interpretation across different research findings less feasible.

The facilitation effect of cognates may depend on a variety of factors. Studies in visual word recognition report that cognate facilitation effects in bilinguals and L2 (i.e., second language) learners are more prominent with a higher degree of orthographic and phonological overlap (e.g., Carrasco-Ortiz, Amengual, & Gries, 2019; Comesaña et al., 2015; Dijkstra et al., 2010). However, differences in the degree of phonological overlap have also led to mixed findings, which suggests that orthographic and phonological overlap may affect bilingual lexical recognition in different ways (e.g., Carrasco-Ortiz et al., 2019; Comesaña et al., 2015; Dijkstra, Grainger, & van Heuven, 1999; Frances, Navarra-Barindelli, & Martin, 2021; Schwartz, Kroll, & Diaz, 2007).

Whereas some studies report facilitation effects of higher phonological overlap in visual word recognition (e.g., Dijkstra et al., 2010), other studies have reported inhibitory effects for higher phonological overlap, instead of facilitation effects, in visual recognition of cognates in language pairs that have similar phonetic repertoires (e.g., Comesaña et al., 2015; Dijkstra et al., 1999). Importantly, evidence of cognate similarity effects in spoken word recognition is still scarce. There is consistent evidence indicating that higher orthographic overlap benefits cognate recognition, but the effects of phonological overlap are still unclear.

The present study investigates cross-linguistic effects of cognates in spoken word recognition. The main goal of the present study is to examine how phonological overlap modulates auditory recognition of cognates in L2 learners of Spanish and English. In addition, the present study also provides a comparison of subjective and objective measures of phonological similarity to test how they correlate with auditory cognate recognition.

Evidence of cross-linguistic facilitation effects of cognates

Cognate facilitation effects have been reported in a variety of studies in visual word recognition (e.g., Dijkstra et al., 2010), spoken word recognition (e.g., Blumenfeld & Marian, 2005), and speech production (e.g., Amengual, 2012, 2016). Cognate effects in word recognition have been observed using different experimental paradigms such as lexical decision tasks (e.g., Carrasco-Ortiz et al., 2019; Dijkstra et al., 2010; Van Hell & Dijkstra, 2002), visual-world paradigm eye-tracking tasks (e.g., Blumenfeld & Marian, 2005), reading tasks (e.g., Aguinaga, 2017), translation tasks (e.g., Tercedor, 2010), word association tasks (e.g., Van Hell & Dijkstra, 2002), and priming tasks with electrophysiological data (e.g., Comesaña et al., 2012), which shows the robustness of the cognate facilitation effect.

Cross-linguistic orthographic overlap has a consistent role in the facilitation effect of cognates. Otwinouska and Szewczyk (2017) investigated the acquisition of cognates and noncognates in Polish learners of English. Participants completed a backward translation task and a rating task in which they rated the confidence of their translations. The task included cognates, noncognates, and interlingual homographs. Results showed that the cognate facilitation effect was modulated by the degree of orthographic similarity between translation pairs. L2 cognate words were learned faster as orthographic overlap increased. Similarly, orthographic similarity facilitation effects were found in Aguinaga Echevarría (2017). Aguinaga Echevarría (2017) investigated how cognate similarity affected cognate recognition in L1 English – L2 Spanish learners. Participants completed a reading task in Spanish and a translation task that contained cognates with varying degrees of orthographic similarity. Results showed facilitation effects of cognates over noncognates, and cognates with higher orthographic overlap yielded more correct responses. Higher orthographic overlap facilitated recognition of cognates in these studies.

In addition to cross-linguistic orthographic overlap, the degree of phonological overlap has also been found to influence word recognition. However, studies investigating the role of phonological overlap in word recognition have measured phonological similarity in several ways. Some studies established phonological overlap by calculating the number of similar phonetic features (Marian & Spivey, 2003) whereas others calculated overlap based on the number of syllables, position of stressed syllable, vowel quality, and phonological context (Comesaña et al., 2012). These measures may be more appropriate for language pairs that have similar phonetic inventories than for language pairs that differ phonologically in a significant way.

Studies have also used subjective similarity rating tasks to determine the degree of overlap among cognates and noncognates (e.g., Comesaña et al., 2012; Dijkstra et al., 1999; Dijkstra et al., 2010). Subjective ratings may tap directly into the actual similarity that listeners perceive. Other studies have used objective measures of string similarity to calculate both orthographic and phonological overlap of cognate and noncognate pairs such as the Levenshtein Distance (LD) (Carrasco-Ortiz et al., 2019), the Normalized Levenshtein Distance (NLD) (Schepens, Dijkstra, & Grootjens, 2012; Schepens, Dijkstra, Grootjens, & van Heuven, 2013), ALINE (Frances et al., 2021; Kondrak, 2000), COGIT (Kondrak, 2001), among others. Relevant to the present study, the LD and the NLD establish form similarity differently, especially for phonological overlap. Whereas the LD considers the number of operations needed to turn one string into another, the NLD considers the distance between sounds based on articulatory features, which makes the NLD a more appropriate measure of phonological overlap than the LD. Importantly, studies have reported that perceptual similarity ratings of bilinguals and monolinguals commonly correlate with objective measures of overlap (Burt et al., 2017; Comesaña et al., 2012; Dijkstra et al., 2010; Gooskens & Heeringa, 2004; Sanders & Chin, 2009). Notably, evidence of how the NLD correlates with auditory ratings of cross-linguistic phonological similarity is scarce, especially for Spanish-English items.

The effects of cross-linguistic phonological overlap on word recognition may depend on the level of language proficiency. Blumenfeld & Marian (2005) investigated the effects of phonological overlap and language proficiency in bilingual auditory recognition of cognates. English-German and German-English bilinguals completed an auditory identification eye-tracking task in which they identified English cognates and non-cognates in picture displays that also contained German competitor words. The German competitor words shared phonological onsets with the English items. Results showed that German dominant participants co-activated

German competitor words when processing both cognate and non-cognate English items; however, English dominant participants exhibited co-activation of German competitor words only when processing English cognates. Both proficiency and phonological overlap modulated the extent of cross-linguistic co-activation of lexical items. Proficiency effects in cognate recognition have also been found in multilingual subjects. Van Hell and Dijkstra (2002) examined the influence of foreign language knowledge on native language performance. Dutch-English-French trilinguals (low and high proficiency) completed a word association task and a lexical decision task in Dutch (L1) in which they encountered L1-L2 cognates, L1-L3 cognates, and L1 non-cognates. Results showed that increased proficiency caused faster responses for cognates over non-cognates. Low proficiency participants did not exhibit cognate advantages, suggesting that a minimum level of proficiency is required to exploit and benefit from cross-linguistic co-activation during L1 processing specifically. However, the role of proficiency in cognate recognition is still unclear since there are also studies showing stronger cognate facilitation effects with lower L2 proficiency (e.g., Bultena, Dijkstra & van Hell, 2014; Pivneva, Mercier & Titone, 2014; Winther, Matusevych & Pickering, 2021).

Phonological effects of cognates have been observed mostly when processing cognates in the L2 than in the L1. Previous studies have reported an inverse phonological effect in which cognates with greater phonological overlap facilitated processing in the L2 through co-activation of L1 cognate items, but the same effect was not found when processing the L1 cognate items (Carrasco-Ortiz et al., 2019; Muntendam et al., 2022). This processing asymmetry is also observed in priming studies in bilinguals in which cognate effects were found only for L2 cognates primed by L1 cognate translations but not vice-versa (Midgley, Holcomb, & Grainger, 2009). L1-L2 processing and activation asymmetries are accounted for in different models of lexical activation such as the Revised Hierarchical Model (RHM) (Kroll & Stewart, 1994). For example, in the RHM, the L1 lexicon mediates the connection between the L2 lexicon and the conceptual level, which implies that the L1 influences L2 processing but not viceversa. Hence, cognate facilitation effects are more commonly observed during L2 processing due to strong co-activation of the L1. However, the RHM may not account for cognate facilitation effects in L1 processing.

Since both orthographic and phonological overlap modulate word recognition, studies have explored the interplay of orthography and phonology in the recognition of cognates. Dijkstra et al. (2010) tested Dutch-English bilinguals using a lexical decision task and a language decision task in which participants read Dutch-English cognates and non-cognates that differed in their level of orthographic and phonological overlap. Results indicated that in the lexical decision task higher orthographic overlap caused faster responses, and increased phonological overlap facilitated recognition of identical cognates only. The language decision task revealed a cognate inhibition effect that increased with orthographic overlap, opposite to the lexical decision task. Orthographic and phonological overlap influenced visual word recognition, but the effects varied depending on task demands. The cognate facilitation effect and the influence of orthographic overlap can be reversed depending on the experimental conditions. Similarly, in Carrasco-Ortiz, Amengual, and Gries (2019), English learners of Spanish and Spanish heritage speakers completed two lexical decision tasks (one in Spanish and one in English) in which they read cognates, non-cognates, and pseudo-words that differed in the degree of orthographic and phonological overlap. Results showed that orthographic similarity facilitated word recognition in both languages for both groups, but phonological similarity only facilitated recognition of Spanish words. Phonological and orthographic similarity influenced word recognition in different ways independently of language dominance.

Facilitation effects of form overlap can also depend on the composition of the stimulus list included in experimental tasks. Comesaña et al. (2015) explored the effects of cross-linguistic similarity and stimulus list composition in word recognition in Catalan-Spanish bilinguals. Participants completed a lexical decision task that included identical and non-identical cognates in the stimulus list and a lexical decision task without identical cognates. Importantly, cognate advantages were observed only in the task that included identical cognates in the stimulus list, which highlights the influence of linguistic context in bilingual lexical activation and recognition. Similar to the findings in Dijkstra et al. (2010) and Carrasco-Ortiz et al. (2019), results of Comesaña et al. (2015) showed facilitation effects for orthographic overlap and inhibition effects for phonological overlap. The results point to representational differences between identical cognates and non-identical cognates as well as differential roles of orthographic and phonological overlap. The present study includes identical cognates in the stimulus list to capture facilitation effects in auditory recognition of cognates.

The differences in the effects of phonological and orthographic overlap may depend on the modality of the task, visual or auditory. Frances, Navarra-Barindelli, and Martin (2021) investigated the effects of form similarity in L2 word recognition across modalities. Late Spanish-English bilinguals completed a visual lexical decision task and an auditory lexical decision task in English. Both tasks included words with high and low phonological and orthographic similarity, fully crossed, as well as identical cognates. Results indicated that form overlap effects vary depending on the modality of the task. Higher orthographic overlap facilitated visual recognition, and higher phonological overlap facilitated auditory recognition. Interestingly, inhibitory effects were observed across modalities and types of similarity. Higher orthographic overlap hindered auditory recognition and higher phonological overlap hindered visual recognition. The results suggest a need for a separation between types of similarity in cognate studies due to the activation of both types of similarity in both modalities. Other studies have also reported facilitation effects of cognates in the auditory modality in Spanish-English bilinguals at lower levels of L2 proficiency but have failed to detect any influence of phonological overlap (Andras et al., 2022). Interestingly, more recent studies have reported that cognate recognition in the auditory modality may be influenced by other phonological factors such as lexical stress (Muntendam et al., 2022) and speaker accent (Frances et al., 2022). More research is needed to further explore the factors that modulate cognate facilitation effects in auditory word recognition.

Lexical frequency influences cognate processing as well. Higher lexical frequency cognates have obtained faster responses than lower frequency cognates in visual word recognition (Carrasco-Ortiz, et al., 2019; Peeters, Dijkstra, & Grainger, 2013). However, the way lexical frequency interacts with phonological and orthographic overlap is still unclear. In the visual lexical decision task of Carrasco-Ortiz et al. (2019), lexical items with higher frequency obtained overall faster response times. However, some items with high phonological and orthographic overlap obtained slower response times, which was attributed to lexical frequency. In addition, in Peeters, Dijkstra, & Grainger (2013), French-English bilinguals completed a lexical decision task in English. Electrophysiological data and response time data were measured. The results showed facilitation effects of cognates, and reaction times decreased with higher lexical frequency in English and French. This effect showed in the N400 amplitude as well. Importantly, all the cognate items used in Peeters et al. (2013) were identical cognates, so there were not different degrees of overlap involved. It seems that frequency effects are clear and robust with cognates that have complete overlap. When different degrees of overlap are present, frequency effects may diminish the cognate facilitation effect (Carrasco-Ortiz et al., 2019).

In summary, a variety of studies on cognate recognition and processing showed that the degree of orthographic overlap, phonological overlap, lexical frequency, task demands, and language proficiency modulate the facilitation effects of cognates. Orthographic and phonological overlap may have different contributions on cognate effects, but lexical frequency may diminish the effects of cross-linguistic form overlap. It is important to note that most of the studies available address cognate recognition and processing in the visual modality with only a few exceptions adressing the auditory modality. It remains unclear how phonological and orthographic overlap affect auditory word recognition; and it is not clear how proficiency modulates the effects of overlap in the recognition of cognates since many studies did not measure proficiency with objective measures but used self-reporting instead. More research is needed in order to assess the role of form overlap, frequency, and proficiency in recognition of cognates in the auditory modality.

Cognates in models of word recognition

The influence of lexical frequency and orthographic/phonological similarity are accounted for in major models of word recognition. For example, the Bilingual Interactive Activation Plus model (BIA+, Dijkstra & Van Heuven, 2002) considers that activation of lexical items is modulated by the degree of orthographic, phonological, and semantic overlap within and across languages. Frequency of use and neighborhood density also influence lexical processing. However, BIA+ is a model designed to explain visual word recognition and it focuses mainly on orthographic representations. Visual word recognition and spoken word recognition involve different processes due to the nature of spoken and written language. Although BIA+ acknowledges cognate facilitation effects, the model does not implement the representation of cognates in its design. In the case of cognates, the assumptions of BIA+ predict that higher phonological overlap, orthographic overlap, and lexical frequency result in faster word recognition. Nonetheless, studies suggest that the interactions between these factors are far more complex and that phonological and orthographic cognate similarity may independently cause differential effects (e.g, Carrasco-Ortiz et al., 2019; Comesaña et al., 2015; Dijkstra, Grainger, & van Heuven, 1999; Frances et al., 2021).

The assumptions of the BIA+ were further developed into the Multilink model (Dijkstra et al., 2018), which is a localist-connectionist model that simulates the recognition and production of cognates and non-cognates. Multilink assumes non-selective access and parallel activation of word form neighbors across languages. It considers effects of lexical similarity, cognate status, L2 proficiency, word length, lexical frequency, task demands, and translation direction. Regarding lexical similarity, Multilink predicts that words are activated depending on the degree of orthographic similarity to the input word and their subjective frequency of usage. To account for orthographic similarity, Multilink uses the normalized Levenshtein distance to calculate the levels of orthographic overlap across items, and it predicts that lower Levenshtein distance (less orthographic overlap) results in longer recognition times. Word forms in Multilink have a frequency-dependent resting level of activation, which may vary depending on the level of L2 proficiency of individuals. Lexical items in the lexicon of high proficiency bilinguals have a higher resting level of activation than those in the lexicon of low proficiency bilinguals. The frequency-dependent resting level of activation modulates word recognition, with words with higher levels being more strongly activated. Importantly, although Multilink includes cognate effects and predicts the experimental data of several studies employing various tasks, it was designed to account for visual word recognition and production. Similar to the BIA+, Multilink focuses on orthographic representations and visual input, but the model could be adapted to account for auditory word recognition as well.

There are other models of word recognition that may also provide accurate predictions for auditory processing of cognates. The Bilingual Language Interaction Network for Comprehension of Speech (BLINCS, Shook & Marian, 2013) is a computational model that assumes different interconnected levels of processing created by dynamic self-organizing maps (unsupervised learning algorithm). Speech comprehension is influenced by audio-visual integration and cross-linguistic interaction. BLINCS assumes four levels of representation: phonological, phono-lexical, ortho-lexical, and semantic. BLINCS considers that a high degree of cross-linguistic interactions occur (co-activation and competition), which are influenced by lexical frequency and neighborhood size. Shared phonology, semantics, and orthography cause increased activation of candidates within and across languages and lexical selection occurs through the matching of the candidates and the input on the different levels. Regarding cognates, BLINCS assumes that cognates have increased, and stronger activation compared to non-cognates due to orthographic, phonological, and semantic overlap. In this model, cognates are represented near each other in the boundaries of language spaces. This model also considers that proficiency modulates competition and activation. For the present study, BLINCS predicts that cognates will have facilitation effects compared to non-cognates due to cross-language activation and that the level of overlap and L2 proficiency will modulate these effects. However, similar to the BIA+, BLINCS does not account for the differential contributions of orthographic and phonological overlap previously observed in cognate studies (e.g., Carrasco-Ortiz et al., 2019).

Another available model that gives specific predictions regarding phonological overlap is the Bilingual Interactive Model of Lexical Access (BIMOLA, Léwy & Grosjean, 2008). In BIMOLA, there are two independent lexicons that are interconnected with three levels of representation: a feature level (shared between languages), a phoneme level (language independent but interconnected), and a word level (language independent but interconnected).

Cross-linguistic competition happens at the feature level whereas within-language competition happens during the phoneme and word level. In BIMOLA, the language mode of a bilingual listener controls cross-linguistic interactions. This model assumes that phonological similarity determines activation of candidates and that the phonemic repertoires of both languages are interconnected. Phonemes that share only some phonological characteristics (e.g., /b/ and /d/) will be more strongly activated than phonemes that have very different characteristics (e.g., /b/ and /s/). BIMOLA does not implement proficiency effects, but since it has a bilingual feature level with a combined inventory of features from both languages, one could assume that a significant level of proficiency in both languages is needed for the bilingual feature inventory to be established. Frequency effects and the degree of activation are taken into consideration assuming that higher frequency causes stronger activation. BIMOLA does not give specific predictions regarding cognates, but it supports stronger co-activation of overlapping lexical items.

A model that can explain the asymmetry of cognate effects in the L1 and the L2 is the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994). RHM considers that there is a strong connection between the L1 lexicon and the conceptual level, but an indirect connection between the L2 lexicon and the conceptual level. RHM implies that L2 processing is mediated by the L1, but at high levels of proficiency, L2 connections to concepts become stronger. The L1-mediated system of RHM predicts that cognate effects are stronger during L2 processing than during L1 processing, a claim that the present study also tests. Some previous studies have found cognate effects in both languages (e.g., Carrasco-Ortiz et al., 2019; Midgley et al., 2011), but others have found cognate effects only in the L1 (e.g., Caramazza & Brones, 1979; Gerard & Scarborough, 1989). However, some assumptions of the RHM could have different implications for cognate recognition. For example, RHM claims that as proficiency increases L2 lexical items strengthen their direct access to the conceptual level without mediation of the L1, which could imply that as proficiency increases lexical access becomes selective and cognate facilitation effects become weaker. In addition, RHM assumes separate lexicons for the L1 and the L2, which could be problematic for the case of cognates because cognate facilitation effects show strong cross-linguistic interactions. RHM does not explicitly account for cognate representation and the role of orthographic/phonological overlap and lexical frequency.

The present study

The present study investigates cross-linguistic effects of cognate similarity in spoken word recognition in native and nonnative speakers of Spanish and English. The present study has four main goals. First, this study examines whether objective measures of string similarity (the Levenshtein Distance and the Normalized Levenshtein Distance) correlate with the subjective similarity ratings of listeners. Previous studies have used different methods to measure cross-linguistic phonological overlap. There is evidence of a positive correlation between the Levenshtein Distance and perceptual distance in Norwegian (Gooskens & Heeringa, 2004) and English (Burt et al., 2017; Sanders & Chin, 2009), and a positive correlation between objective and subjective measures of overlap has been found across languages in Portuguese-English bilinguals (Comesaña et al., 2012) and Dutch-English bilinguals (e.g., Dijkstra et al., 2010; Schepens et al., 2013), but evidence from English-Spanish is still scarce. The present study expects to find a strong correlation between the LD/NLD and subjective similarity ratings.

Second, the present study examines whether cognates are recognized faster than non-cognates in spoken word recognition, and if so, whether cognate facilitation effects are observed during both L1 and L2 spoken word recognition. Most of the evidence of cognate effects has been observed in visual word recognition, and evidence in the auditory modality is scarce. Some studies showed that cognate effects are present during both L1 and L2 word recognition (e.g., Midgley et al., 2011; van Hell & Dijkstra, 2002), but others have failed to find facilitation effects in the L1 (e.g., Caramazza & Brones, 1979; Gerard & Scarborough, 1989). Cognate facilitation effects in L1 processing may appear at a certain level of L2 proficiency (e.g., Midgley et al., 2011; van Hell & Dijkstra, 2002). The present study expects to find cognate facilitation effects in both the L1 and the L2, with L2 facilitation effects being more robust, and L1 facilitation effects being modulated by L2 proficiency.

Third, this study tests the influence of orthographic and phonological overlap on auditory recognition of cognates. Models of word recognition such as BIA+ (Dijkstra & Van Heuven, 2002), Multilink (Dijkstra et al., 2018), BLINCS (Shook & Marian, 2013), and BIMOLA (Léwy & Grosjean, 2008) support that higher cross-linguistic overlap results in stronger lexical co-activation and faster recognition. Some studies have found evidence that is consistent with this claim (e.g., Dijkstra et al., 2010; Marian & Spivey, 2003), but others have found that orthographic and phonological overlap may contribute to word recognition in different ways (e.g., Carrasco-Ortiz et al., 2019; Comesaña et al., 2015; Dijkstra et al., 1999; Frances et al., 2021; Schwartz et al., 2007). The present study anticipates auditory recognition of cognates to be modulated by the degree of orthographic and phonological overlap. Since the present study employs auditory tasks, phonological overlap may cause facilitation effects whereas orthographic overlap may cause inhibitory effects, as in previous studies (e.g., Frances et al., 2021).

Finally, this study also evaluates the role of L2 proficiency in auditory recognition of cognates. BLINCS (Shook & Marian, 2013) predicts that stronger cross-linguistic co-activation happens at higher levels of L2 proficiency; and Multilink (Dijkstra et al., 2018) suggests that higher proficiency causes higher levels of resting activation of lexical items. Some studies reported cognate facilitation effects at higher levels of L2 proficiency (e.g., Blumenfeld &

Marian, 2005; Dijkstra et al., 2010), but other studies showed facilitation effects at lower levels of L2 proficiency (e.g., Bultena et al., 2014; Pivneva et al., 2014). The present study expects cognate facilitation effects in the L1 to increase as L2 proficiency increases. When processing cognates in the L2, facilitation effects may be more robust with lower L2 proficiency due to higher co-activation of the L1.

Methodology

Participants

The sample pool will consist of 120 participants: 60 Spanish learners of English (Spanish L1-English L2) and 60 English learners of Spanish (English L1-Spanish L2). An a priori power analysis was conducted using the *SIMR* package (Green & MacLeod, 2016) in *R* (R Core Team, 2020) to test the difference between two group means using a two-tailed test, a medium effect size (d= .50), and an alpha of .05. The analysis was performed following the procedures in Green & MacLeod (2016). The power analysis was run using 1000 simulations. Mean differences and the size of the fixed effect were calculated by considering the extent of cognate facilitation effects reported in previous studies (Comesaña et al., 2015; Valente, 2017). The data was simulated according to the design of the experimental tasks of the present study. Results based on 1000 simulations showed that a total sample of at least 108 participants with two equal sized groups of n= 54 was required to achieve a power of $\geq$ .80 and detect a fixed effect with size 0.06. Figure 1 shows the power curve of fitting the model to 10 different automatically chosen subsets. The smallest subset represents the power of a sample size of 3 participants per group, and the largest subset represents the power of a sample size of 60 participants per group.

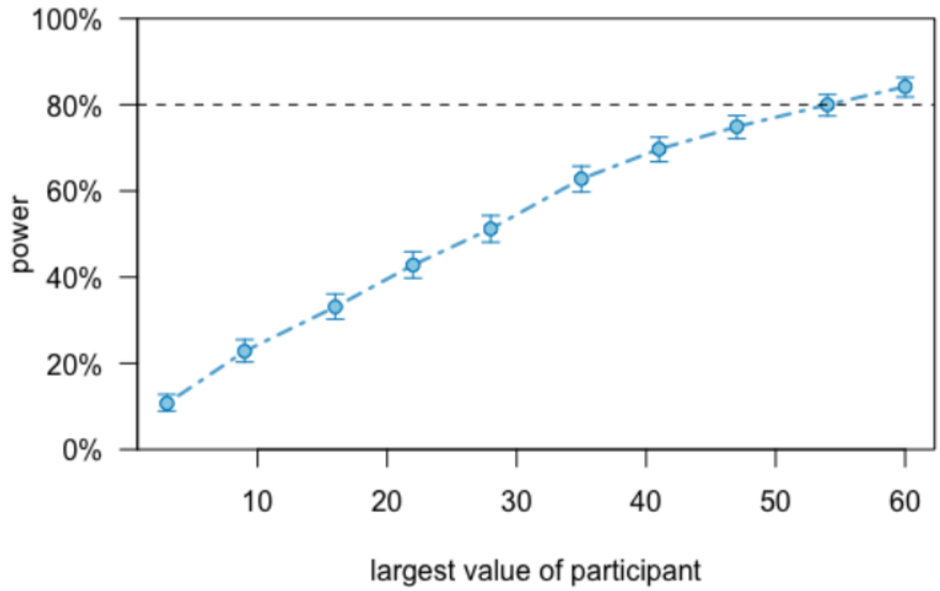


Figure 1. Power (95% CI) to detect a fixed effect with size 0.06, calculated over a range of sample sizes using the powerCurve function of the *SIMR* package. The number of distinct values for the variable *participant* is varied from 3 to 60.

Both groups of participants will include L2 speakers of all levels of proficiency. Proficiency in Spanish and English will be measured using the LexTALE test (Lemhöfer & Broersma, 2012) and the LexTALE-ESP test (Izura et al., 2014; Lemhöfer & Broersma, 2012). Participants will be recruited from a large university in the northeast of the US and through the Prolific.ac online experimental platform. The Spanish L1-English L2 group will include subjects whose first language is Spanish, were born and raised in a Spanish-speaking country, and had no intensive exposure to English before puberty. The English L1-Spanish L2 group will consist of subjects whose first language is English, were born and raised in the United States, and had no intensive exposure to Spanish before puberty. Participants who have had intensive exposure to languages other than Spanish and English will be excluded from the study. A background questionnaire will be used to gather information about participants' linguistic profiles. The background questionnaire will be delivered in the participants' L1 as a survey. The questionnaire will ask about participants' age, age of onset of acquisition of Spanish, age of onset of acquisition of English, mode of acquisition, years of exposure to Spanish, English, and other languages, years of school instruction, location and length of time abroad, percentage of use of their languages, and purposes for which they use their languages.

Materials and procedure

Participants will complete five tasks: (1) Auditory Lexical Decision Task in Spanish, (2) LexTALE-Esp, (3) Auditory Lexical Decision Task in English, (4) LexTALE, and (5) Similarity Rating Task.

Proficiency tests

Participants will be asked to complete two proficiency tests, one in Spanish and one in English. The Lexical Test for Advanced Learners of English (LexTALE) (Lemhöfer & Broersma, 2012) will provide a measure of participants' proficiency by assessing vocabulary size in English in a lexical decision task. Participants will read a total of 60 lexical items (40 English real words and 20 pseudowords) and indicate whether the items are real words in the English language or not with a key press. The pseudowords in the LexTALE are orthographically and phonologically legal constructions for English. Scoring in the LexTALE is based on the number of correct and incorrect responses, with incorrect responses being penalized. The Lexical Test for Advanced Learners of Spanish (LexTALE-ESP) (Izura et al., 2014; Lemhöfer & Broersma, 2012) is a modified version of the LexTALE that measures proficiency in Spanish. Participants will read a total of 90 lexical items (60 Spanish real words and 30 pseudowords) and indicate whether the items are existing words in Spanish or not with a key press. As in the LexTALE, pseudowords in the LexTALE-ESP are legal constructions and incorrect responses are penalized. In the present study, proficiency will be treated as a continuous variable.

Auditory lexical decision tasks

Participants will complete two Auditory Lexical Decision Tasks (ALDT), one in Spanish and one in English. The order of the languages of the ALDTs and the proficiency tests will be counterbalanced across participants. In both tasks, participants will listen to words (cognates and non-cognates) and pseudo-words and indicate whether these items are real words or not by pressing a key ('1' for Real words, '0' for Non-words). Both ALDTs will present stimuli items aurally while participants look at a screen that displays two choices (Real, Not Real), on each side of the screen. Trials will begin with a fixation cross in the center of the screen that will disappear after 500 ms and both choices (Real, Not Real) will be displayed on the sides of the screen. 500 ms after the appearance of the choices, the target word will be presented aurally. Participants will indicate as quickly as possible whether the item they hear is a real word or not by pressing keys '1' or '0' and their responses will be registered using a computer keyboard. Accuracy and reaction time (RT) will be measured. RT will be measured from the onset of the stimulus word. The tasks will start with 10 practice trials in order to familiarize participants with the experimental procedure. Participants will receive written instructions in Spanish or English based on the language of the ALDT.

The stimuli lists consist of a total of 400 experimental items: 100 cognate pairs and 100 non-cognate pairs in English and Spanish (see Supplementary Materials). Cognate and noncognate words in each language were controlled for orthographic length and lexical frequency. Orthographic length and lexical frequency values were calculated using the web application NIM (Guasch, Boada, Ferré, & Sánchez-Casas, 2013). Orthographic length values in

English cognates (mean = 5.13, *SD* = 1.03) and noncognates (mean = 4.96, *SD* = .91) were not statistically different: $t(194.93) = 1.24$, $p = .218$. Similarly, orthographic length values in Spanish cognates (mean = 5.57, *SD* = 1.10) and noncognates (mean = 5.46, *SD* = 1.39) were not statistically different: $t(188.39) = .62$, $p = .536$. Lexical frequency was established using the word frequency per million of NIM (Guasch et al., 2013). NIM uses the LEXESP database as reference for Spanish lexical frequency and the British National Corpus as reference for English lexical frequency. To obtain a comparable measure of frequency across English and Spanish, the frequency values were converted to the Zipf scale, which is a standardized scale of word frequency per million logged to the base of 10 + 3 (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Lexical frequency of English cognates (mean = 1.70, *SD* = .46) and noncognates (mean = 1.64, *SD* = .56) was not statistically different: $t(190.39) = .83$, $p = .408$. Similarly, frequency of Spanish cognates (mean = 1.61, *SD* = .40) and noncognates (mean = 1.48, *SD* = .60) was not statistically different: $t(173.4) = 1.8$, $p = .073$.

The cognates and non-cognates have varying degrees of orthographic and phonological overlap, which was operationalized using two objective measures: the Levenshtein Distance (Yarkoni, Balota, & Yap, 2008) and the Normalized Levenshtein Distance (Schepens, Dijkstra, & Grootjen, 2012). The Levenshtein Distance (LD) calculates the similarity between two strings based on the number of substitution, insertion, or deletion operations needed to turn one string into the other. For example, for *air* and *aire*, the LD value for orthographic overlap is 1 due to the insertion/deletion of "e". A higher LD value corresponds to lower orthographic overlap because a greater number of operations is needed to turn one string into the other. A lower LD value corresponds to higher overlap because a lower number of operations is needed to turn one string into the other. Previous studies have used the LD to measure phonological overlap as well (e.g., Carrasco-Ortiz et al., 2019; Vitevitch, 2012) by applying it to the phonetic transcription of lexical items. Phonological overlap was established based on the number of operations needed to turn the phonetic transcription of an item into the transcription of another item. For instance, for *air* /ɛr/ and *aire* /aiɾe/, the LD value for phonological overlap is 4 because all four segments have to be either substituted or inserted/deleted to turn one transcription into the other. However, using the LD to calculate phonological overlap is problematic because it does not take into consideration differences and similarities in the articulatory features of phonemes. There are sounds such as /p/ - /b/, /d/ - /t/, and /k/ - /g/ that share the same manner and place of articulation but only differ in voicing. The LD does not account for this phonetic overlap. For this reason, a second measure of form overlap was also used in the present study, the Normalized Levenshtein Distance (NLD) (Schepens et al., 2012; Schepens et al., 2013). For orthographic overlap, the present study used the NLD as a normalization of the LD. For phonological overlap, the study employed a modified version of the NLD (Schepens et al., 2013) that was designed especially for phonology considering phoneme similarities.

The NLD calculates orthographic similarity in a semi-continuous way with values between 0 and 1. A lower NLD value corresponds to lower orthographic overlap, and a higher NLD value corresponds to higher orthographic overlap. For example, the NLD value for orthographic similarity in the non-cognate pair *manzana – apple* is 0.14, but the NLD value for the cognate pair *ácido – acid* is 0.8. The NLD is a normalized measure of the LD that includes substitutions costs and word length. In the present study, NLD values were used to distinguish between cognate and non-cognate items. Lexical items regarded as cognates have a NLD value of .5 or higher, and non-cognate items have a NLD value of less than .5 (see Schepens et al., 2012). Statistical analyses showed that orthographic NLD values for English-Spanish cognates (mean = .78, *SD* = .13) and noncognates (mean = .12, *SD* = .095) were statistically different: $t(179.68) = 40.875$, $p < .001$.

The NLD measures for orthographic and phonological similarity of Schepens et al. (2013) have been validated with subjective similarity ratings in different languages such as Dutch and English. This NLD includes different substitution costs depending on the degree of similarity between the phonemes in the phonetic representations of words. Substitution costs are based on the distinctive phonetic feature space as presented in the International Phonetic Alphabet (IPA). Schepens et al. (2013) calculated substitution costs based on the Euclidean distance in the respective IPA vowel or consonant space. The NLD with the respective substitution costs for articulatory similarity were applied to the phonetic transcriptions of the cognate items in order to obtain a measure of phonological overlap, as in Schepens et al. (2013). The phonetic transcriptions of the English items were obtained using the web application *toPhonetics*, which is an online converter of English text to IPA phonetic transcription. The phonetic transcriptions of the Spanish items were obtained using the *Transcriptor Castellano* of The Musa Academy. The phonological NLD of cognates in the present study was on average .81 (SD = .08).

All the cognates included in the present study have values of orthographic and phonological NLD of more than 0.5, and the noncognates have values of less than 0.5. The orthographic NLD values and the orthographic LD values were obtained using the web application NIM (Guasch et al., 2013). The phonological LD values were obtained using the *VWR* package in R (Keuleers, 2013). The phonological NLD values for the cognates were obtained from the Dataset S1 provided by Schepens et al. (2013). All values can be found in the Supplementary Materials.

For the ALDTs, the experimental items will be divided into two presentation lists per language. Each list will contain 50 cognates and 50 non-cognates. The presentation lists will be counterbalanced so that participants do not encounter a Spanish word and its English translation across both ALDTs. A total of 100 pseudo-words will be included in each ALDT, a ratio of words to non-words of 1:1 as in previous studies (Dijkstra et al., 2010; Comesaña et al., 2015). The pseudo-words in the ALDTs will be orthographically and phonologically legal constructions in each language.

Similarity rating task

Participants will complete a Similarity Rating Task (SRT) in which they will listen to Spanish and English translation pairs and rate the phonological similarity between the words using a six-point Likert scale (1 = totally different, 6 = totally similar). Participants will listen to the same cognates and non-cognates used in the ALDTs. Trials will begin with a fixation cross in the center of the screen. 500 ms later, the fixation cross will disappear and the rating options will appear on the screen. 500 ms after the rating options appear, participants will be presented aurally with a Spanish word followed by its English translation. Participants' ratings will be registered using a computer keyboard. The ratings obtained in this task will be analyzed with the LD and NLD values previously calculated for the experimental items in order to see if perceived similarity correlates with the string similarity provided by the Levenshtein measures. Participants' ratings and the Levenshtein values will be included in the analysis of the ALDTs in order to see which measure of overlap provides better predictions of participants' lexical decisions.

Data analyses

In order to test whether subjective phonological similarity correlates with objective measures of similarity, the ratings obtained in the Similarity Rating Task and the LD and NLD values for phonological distance previously calculated will be submitted to a bivariate correlation analysis. The values of the subjective and the objective variables will be converted to standardized scores so that they are in the same scale and have a mean of 0. The standardized scores will be used to calculate a Pearson's correlation coefficient. The Pearson's correlation coefficient provides values between 1 and -1, with values closer to 0 indicating weaker correlations. The bivariate correlation analysis will be conducted using the *Stats* package in R (R Core Team, 2020).

In order to assess cognate facilitation effects in spoken word recognition in Spanish and English, the data of both Auditory Lexical Decision Tasks will be analyzed separately in a similar way. Both ALDTs will measure response times and correct/incorrect responses. Correct responses will be automatically coded as "1" and incorrect responses will be coded as "0." RTs of the pseudo-words and incorrect responses will be excluded from the analysis. Pseudo-words will be treated as filler items. RTs shorter than 100 ms will also be excluded from the analysis. Since the stimuli items differ in length, the duration in milliseconds of each word will be subtracted from the total RTs so that only RTs after the offset of the stimuli word are included in the analysis. Outliers or influential data points will be detected by calculating the Cook's distance measure.

To test how the cognate status, phonological overlap, orthographic overlap, and proficiency modulate auditory word recognition in Spanish and English, RTs will be analyzed using a linear mixed effects model. The analysis will use standardized RTs as the response variable as a function of the fixed effects group (English-L1, Spanish-L1), phonological overlap, orthographic overlap, and proficiency. The categorical fixed effect group will be dummy coded with Spanish-L1 set as the baseline. The random effects structure will include by-subject and by-item random intercepts with random slopes for phonological and orthographic overlap. Main effects and interactions will be evaluated by hierarchically partitioning the variance via nested model comparisons. Alpha will be set at 0.05.

There is a possibility that the variables phonological overlap and orthographic overlap are autocorrelated and that they can predict the variance of each other. For this, before carrying out the analyses, a Pearson's correlation analysis will be conducted using both variables of overlap. If there is a high correlation between them, a residualization process will be applied in which two variables will be created: one to capture the effect of phonological overlap without orthographic overlap and one for the effect of orthographic overlap without phonological overlap, following the analysis employed in Carrasco-Ortiz et al. (2019). All analyses will be carried out using R (R Core Team, 2020). The package *lme4* (Bates et al., 2015) will be used to fit the mixed effects models, and the package *emmeans* (Lenth, 2021) will be used for multiple comparisons.

Expected results and implications

The first research question addresses whether objective measures of similarity (the Levenshtein Distance measure and the Normalized Levenshtein Distance measure) correlate with the subjective perceptual similarity ratings obtained in a similarity rating task. Previous studies on word recognition have used subjective similarity rating tasks (e.g., Dijkstra et al., 1999; Dijkstra et al., 2010) and objective measures of similarity (e.g., Carrasco-Ortiz et al., 2019; Kondrak, 2000, 2001; Schepens et al., 2012; Schepens et al., 2013) to establish the degree of form overlap between lexical items. Specifically, a strong positive correlation has been reported between the Levenshtein distance and perceptual distance in Norwegian (Gooskens & Heeringa, 2004) and English (Burt et al., 2017; Sanders & Chin, 2009), and a positive correlation has been found between objective and subjective measures of overlap across languages in Portuguese-

English bilinguals (Comesaña et al., 2012) and Dutch-English bilinguals (e.g., Dijkstra et al., 2010; Schepens et al., 2013). However, evidence from Spanish is scarce. The present study expects to find a strong correlation between the objective measures of similarity and the perceptual similarity ratings, as in available studies. It is important to note that the LD and the NLD establish form similarity differently, especially for phonological overlap. Unlike the LD, the NLD considers the distance between sounds based on articulatory features, which makes the NLD a more appropriate measure of phonological overlap than the LD. Thus, the present study expects to find a stronger positive correlation between the NLD and the subjective ratings than between the LD and the subjective ratings. The present study will test which of the two objective measures better resembles perceptual similarity. In addition, if a strong correlation is found between the NLD and the perceptual ratings, this study will expect these two measures to account for the patterns of RTs in the data equally. If a strong correlation is not observed between the NLD and the similarity ratings, this study will test which of the 3 measures of overlap better predicts the patterns of RTs observed in the data, and will discuss how this specific measure of similarity relates to previous findings.

The second research question examines whether cognate facilitation effects are observed in spoken word recognition in the L1 and the L2. Previous studies have provided mixed findings. Some studies found cognate facilitation effects in both the L1 and the L2 (e.g., Midgley et al., 2011; van Hell & Dijkstra, 2002) whereas others found facilitation effects only in the L2 (e.g., Caramazza & Brones, 1979; Gerard & Scarborough, 1989). Models such as the Revised Hierarchical Model (Kroll & Stewart, 1994) predict that L1 lexical items are strongly activated during L2 processing, but L2 lexical items are not strongly activated during L1 processing, especially at lower levels of proficiency. Importantly, there is evidence suggesting that cognate facilitation effects during L1 processing are more likely to be observed with higher L2 proficiency (e.g., Midgley et al., 2011; van Hell & Dijkstra, 2002). However, most of the studies addressing cognate effects have used visual word recognition tasks, with spoken word recognition evidence still being scarce. Based on previous studies and the RHM (Kroll & Stewart, 1994), the present study expects to detect cognate facilitation effects more strongly during L2 spoken word recognition than during L1 spoken word recognition. Consistent with previous findings, the current study anticipates that L2 proficiency will modulate facilitation effects in the L1, with higher proficiency subjects being more likely to exhibit cognate facilitation effects in L1 processing. If this is the case, this finding will provide evidence supporting the asymmetry and the directionality of cross-linguistic influence as explained in the RHM (Kroll & Stewart, 1994). In contrast, if cognate facilitation effects are observed during L1 processing as strongly as in L2 processing, even for low proficiency subjects, the findings will provide evidence against the asymmetry assumed in the RHM.

The third research question investigates how orthographic and phonological overlap modulate auditory recognition of cognates. Models such as BIA+ (Dijkstra & Van Heuven, 2002), Multilink (Dijkstra et al., 2018), BLINCS (Shook & Marian, 2013), and BIMOLA (Léwy & Grosjean, 2008) indicate that higher cross-linguistic overlap facilitates lexical activation and recognition. These models also consider that cognates have increased co-activation. Previous studies have provided evidence supporting that higher form overlap resulted in faster word recognition (e.g., Dijkstra et al., 2010; Marian & Spivey, 2003, Carrasco-Ortiz et al., 2019), but other studies have found that orthographic and phonological overlap affect word recognition in different ways (e.g., Carrasco-Ortiz et al., 2019; Comesaña et al., 2015; Dijkstra et al., 1999; Frances et al., 2021; Schwartz et al., 2007). Specifically, there is evidence of an interaction between the type of form overlap and the modality of the tasks, with orthographic overlap facilitating visual word recognition but not auditory word recognition and phonological overlap facilitating auditory word recognition but not visual word recognition (Frances et al., 2021). In line with the models and studies previously mentioned, the present study predicts that phonological and orthographic overlap will modulate auditory recognition. However, since this study employs auditory tasks, phonological overlap may cause facilitation effects, and orthographic overlap may cause inhibitory effects, or no effect at all. If this is the case, the findings will support previous studies showing differential roles of orthographic and phonological overlap (e.g, Carrasco-Ortiz et al., 2019; Frances et al., 2021). The findings will inform models of word recognition about the need to acknowledge modality dependent effects of cross-linguistic form overlap. If both orthographic and phonological overlap have facilitation effects in auditory recognition, which has not been observed in previous studies, the findings would still be in line with the predictions of the models discussed. In addition, there is evidence that lexical frequency modulates processing of identical cognates (Peeters et al., 2013) and that lexical frequency may modulate the effects of cross-linguistic form overlap (Carrasco-Ortiz, et al., 2019). Consistent with this evidence, the present study expects that higher-frequency cognate items are recognized faster than lower-frequency cognate items. However, the relationship between lexical frequency and cross-linguistic overlap is still uncertain since it has been reported that frequency effects may overturn the influence of overlap (Carrasco-Ortiz, et al., 2019).

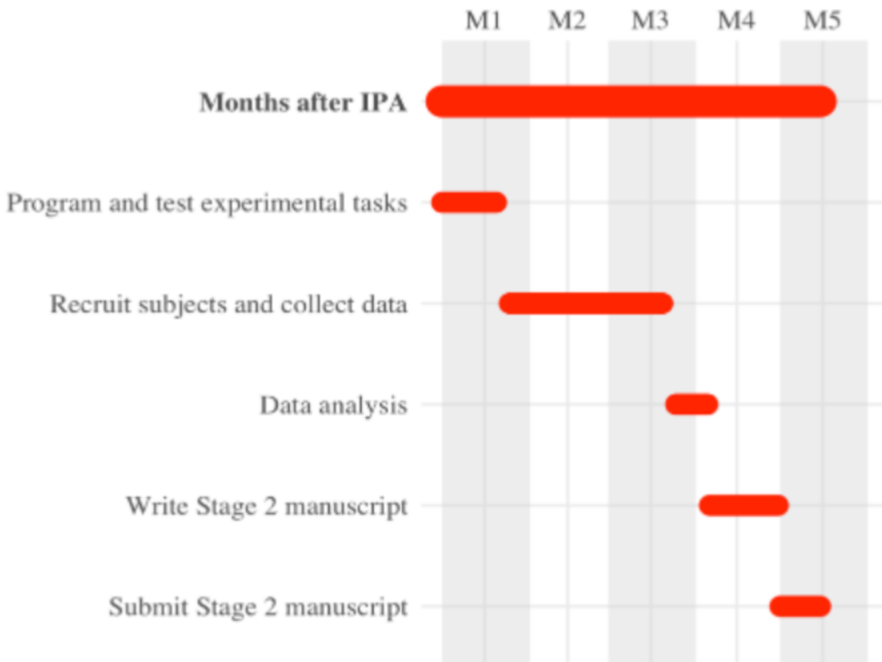
The fourth research question assesses how L2 proficiency modulates auditory recognition of cognates. The BLINCS model considers that cross-linguistic activation is modulated by L2 proficiency, with stronger cross-linguistic co-activation happening at higher levels of proficiency. Similarly, Multilink (Dijkstra et al., 2018) indicates that the resting level of activation of lexical items depends on the level of L2 proficiency, with higher proficiency causing higher levels of activation. Based on these models and available studies, the present study predicts that L2 proficiency will modulate auditory recognition of cognates. Cognate facilitation effects will be more robust with higher proficiency. If so, this finding will provide evidence supporting the BLINCS and Multilink. In addition, evidence shows that cognate facilitation effects during L1 lexical processing are more likely to be observed with higher proficiency (van Hell & Dijkstra, 2002). Consistent with this evidence, the present study expects to find cognate facilitation effects in the L1 with higher L2 proficiency. Many models of lexical processing do not account for the influence of increasing L2 proficiency and language experience (e.g., Dijkstra & Van Heuven, 2002; Léwy & Grosjean, 2008). If proficiency effects are found in the present data, the finding will add to the growing body of evidence of proficiency effects in L2 processing. Future models should account for how the processes of lexical access and processing change as L2 proficiency increases.

Supplementary Materials

A list of the stimuli words used in the present study is available on Open Science Framework, which can be accessed at: https://osf.io/765yr/?view_only=4355be6797a84c0e946c79e662b4da7

Timeline

Time for completion of the research and re-submission:



Protocol Transparency

The author confirms that, following Stage 1 in-principle acceptance (IPA), the approved protocol will be registered in the Open Science Framework repository. The registration will be kept private until submission of the Stage 2 manuscript. The author also confirms that informed consent will be obtained from every subject that participates in the study and that the study has approval of a local Ethical Committee.

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